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Title: Randomized Discrepancy Bounded Local Search for Transmission Expansion Planning

Author(s): Russell Bent
W. Brent Daniel

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Los Alamos
NATIONAL LABORATORY
EST. 1943

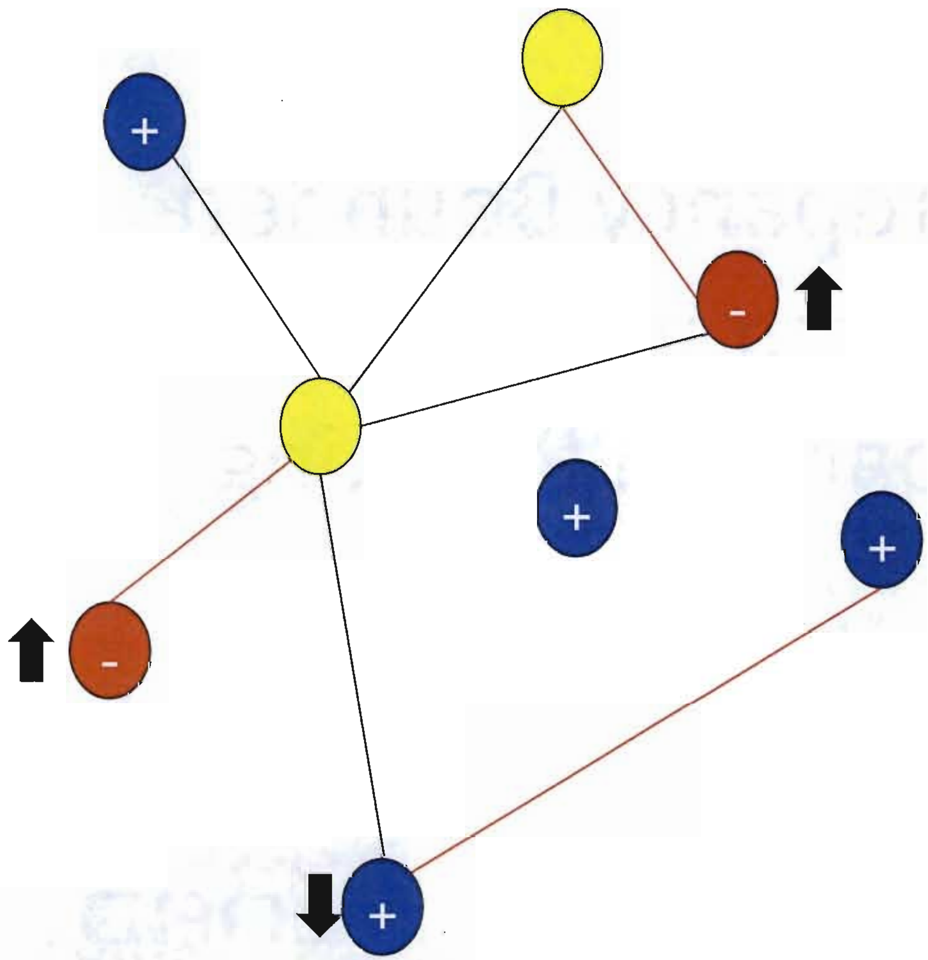
Abstract

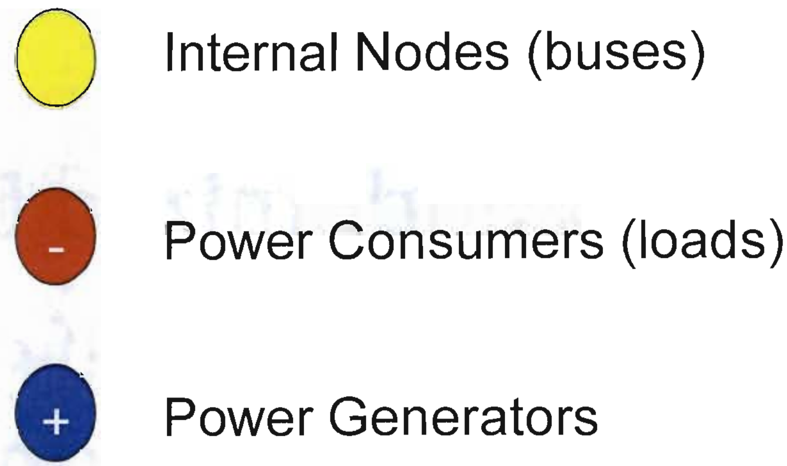
In recent years the transmission network expansion planning problem (TNEP) has become increasingly complex. As the TNEP is a non-linear and non-convex optimization problem, researchers have traditionally focused on approximate models of power flows to solve the TNEP. Existing approaches are often tightly coupled to the approximation choice. Until recently these approximations have produced results that are straight-forward to adapt to the more complex (real) problem. However, the power grid is evolving towards a state where the adaptations are no longer easy (e.g. large amounts of limited control, renewable generation) and necessitates new approaches. Recent work on deterministic Discrepancy Bounded Local Search (DBLS) has shown it to be quite effective in addressing this question. DBLS encapsulates the complexity of power flow modeling in a black box that may be queried for information about the quality of proposed expansions. In this paper, we propose a randomization strategy that builds on DBLS and dramatically increases the computational efficiency of the algorithm

Randomized Discrepancy Bounded Local Search for Transmission Expansion Planning

Russell Bent and W. Brent Daniel

Transmission Expansion Planning





Upgrade an electric power system to accommodate changes in demand and generation

- Eliminate constraint violations
- Minimize expansion cost

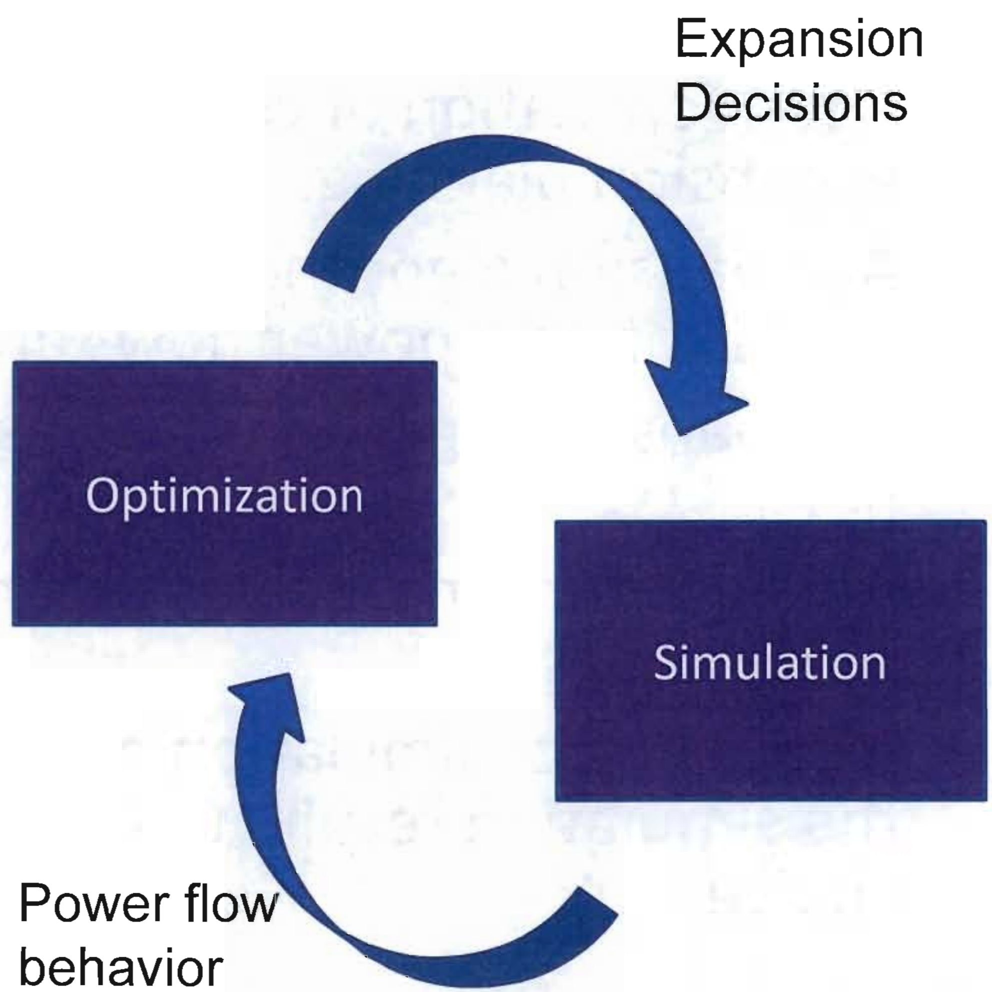
IEEE PES Power & Energy Society IEEE

Key Contributions

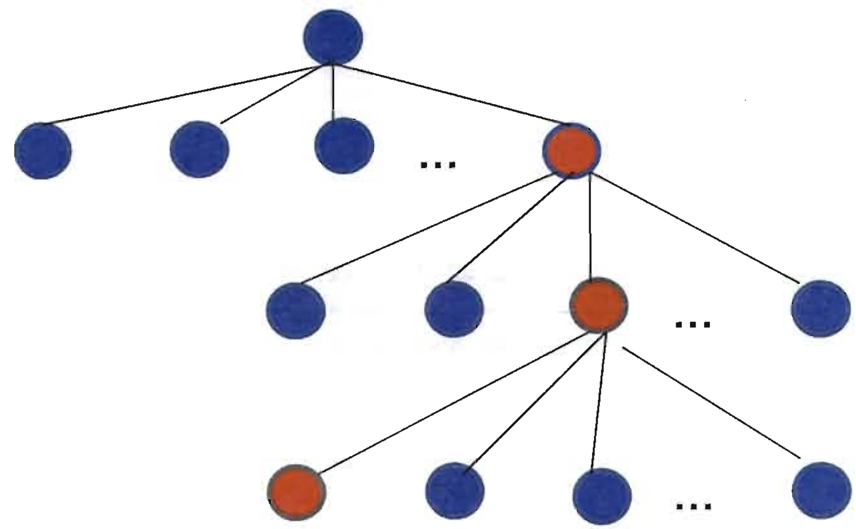
- A randomization of constructive algorithms for expansion planning.
- A expansion algorithm that is decoupled from the details of how power flows are modeled.
- A expansion algorithm that uses AC models of power flow.
- An algorithm that scales to large scale realistic problems.
- A coupling of simulation and optimization that allows the simulation results to influence the optimization choices

Algorithm Overview

- Simulation Optimization
- Encapsulate models difficult to represent in a *black box (simulation)*
- Typically used to evaluate objective function or feasibility
- Simulation results inform optimization choices



Algorithm Overview



- Order expansion options according to a constructive heuristic
- Choose the i^{th} option, where i = (RANDOM([0,1])^{ß} * # possible expansions)

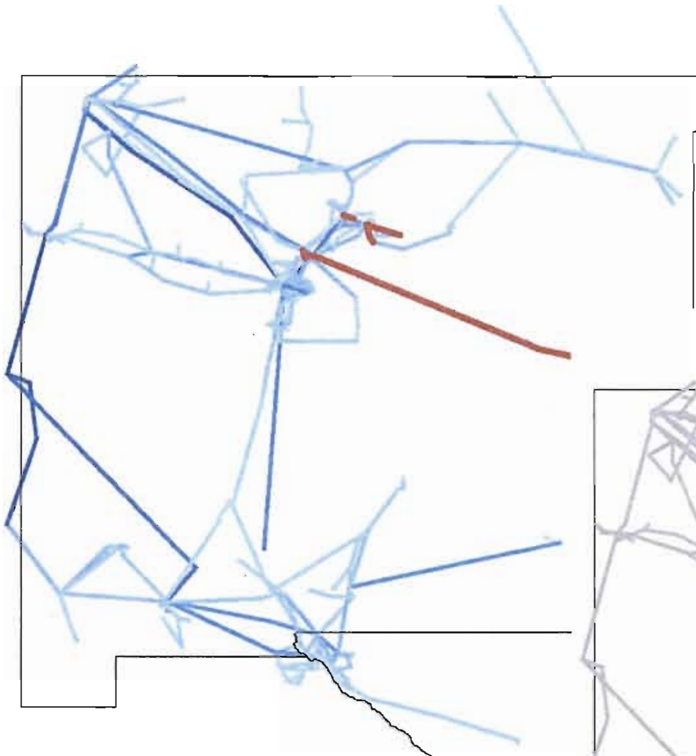
Key Results

	DC	AC
G1	390K	1316K
G2	392K	1977K
G3	272K	1003K
G3	381K	1978K

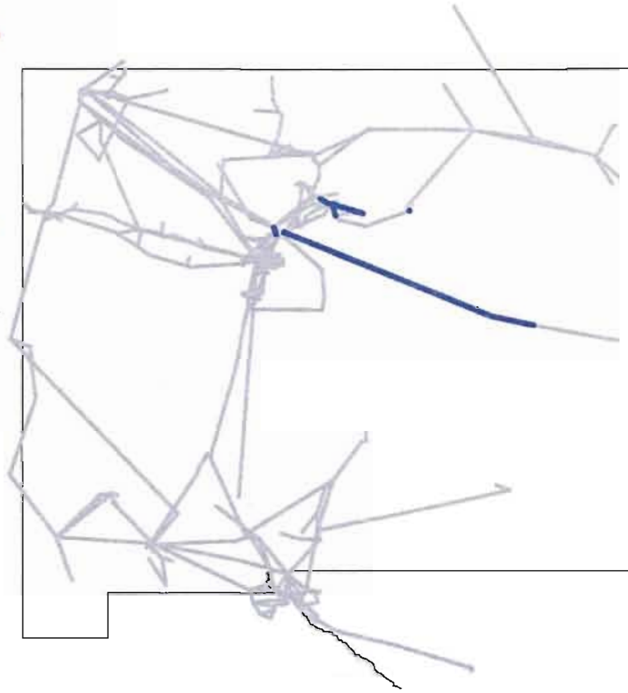
- Feng and Hill benchmarks based on IEEE RTS problems

- Expansion based on AC modeling considerable more expensive than DC modeling

Key Results



- 2020 load and generation projections for New Mexico
- 1700 MVA of overloads in 31 corridors



- 30 circuits added to 28 corridors
- 300 Million in expansion costs

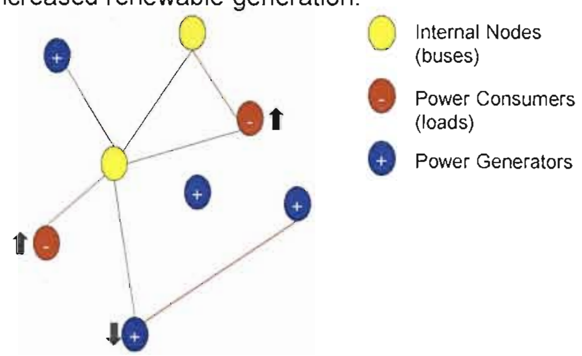
PES 2011

Randomized Discrepancy Bounded Local Search for Transmission Expansion Planning

R. Bent and W. Brent Daniel   Energy and Infrastructure Analysis Group (D-4)

Problem Statement

Upgrade and expand electric power transmission to meet changes in demand and generation, in particular increased renewable generation.



Challenges

1. Power flow modeling makes the problem mixed-integer, nonlinear, non-convex, and divergent

$$P_i = \sum_{k=1..n} |V_i||V_k|(c_{ik}\, g_{ik} \cos(\Theta_i-\Theta_k) + c_{ik}\, b_{ik} \sin(\Theta_i-\Theta_k))$$
$$Q_i = \sum_{k=1..n} |V_i||V_k|(c_{ik}\, g_{ik} \sin(\Theta_i-\Theta_k) + c_{ik}\, b_{ik} \cos(\Theta_i-\Theta_k))$$

Literature typically approximates the equations to (the linearized DC equations)

$$P_i = \sum_{k=1..n} c_{ik}\, g_{ik}\, (\Theta_i-\Theta_k)$$

Assumed easy to adapt to original model **if**

- Generation is adjustable
- Power flows are "well-behaved" (voltages near 1.0 pu)
- Does not necessarily hold when large amount of generation is uncontrollable (wind, solar)

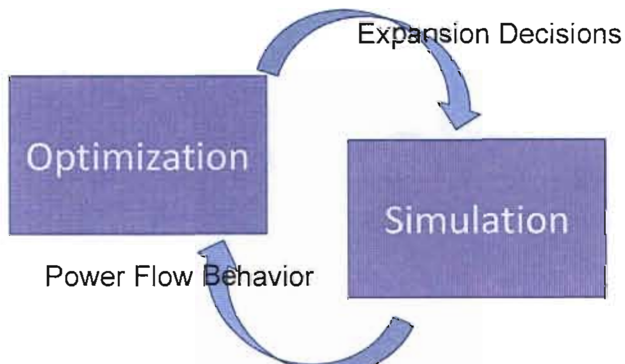
2. Existing algorithms tailored to specific models of power flow

3. Generalize and augment existing constructive heuristics.

4. Scalability to regional level planning

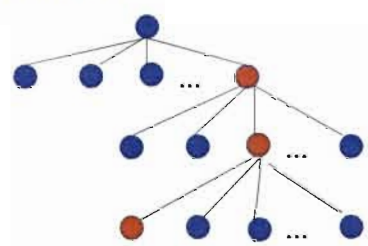
Simulation Optimization

Power flow model (simulation) treated as a black box that may be queried by an optimization procedure.



Optimization procedure is independent of the power flow model.

Optimization: Discrepancy Bounded Local Search



1. Use a constructive heuristic to order possible expansions
2. Choose the i[th] expansion, where i = (RANDOM([0,1])$^{\beta}$ * # possible expansion)
3.. ß is parameter used to control how closely the heuristic is followed.
4. Repeat until the objective function degrades δ times in a row.
5. Repeat steps 1-3 *P* times.

Results

discover LDRD

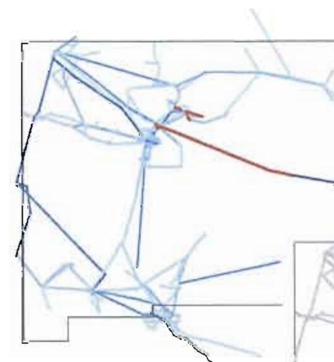
IEEE 24 Bus Benchmark, 41 Lines

Problem	DC Cost	# Circuits Added	AC Cost	# Circuits Added
G1	390K	11	1316K	32
G2	392K	11	1977K	48
G3	272K*	10	1003K	29
G4	381K	9	1978K	41

* A result of 218K exists in the literature

Expansions based on AC models require considerable additional cost

Load and Generation growth projections for New Mexico in 2020



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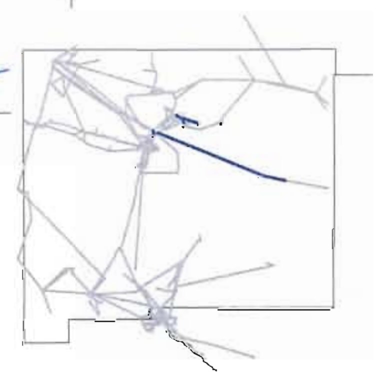

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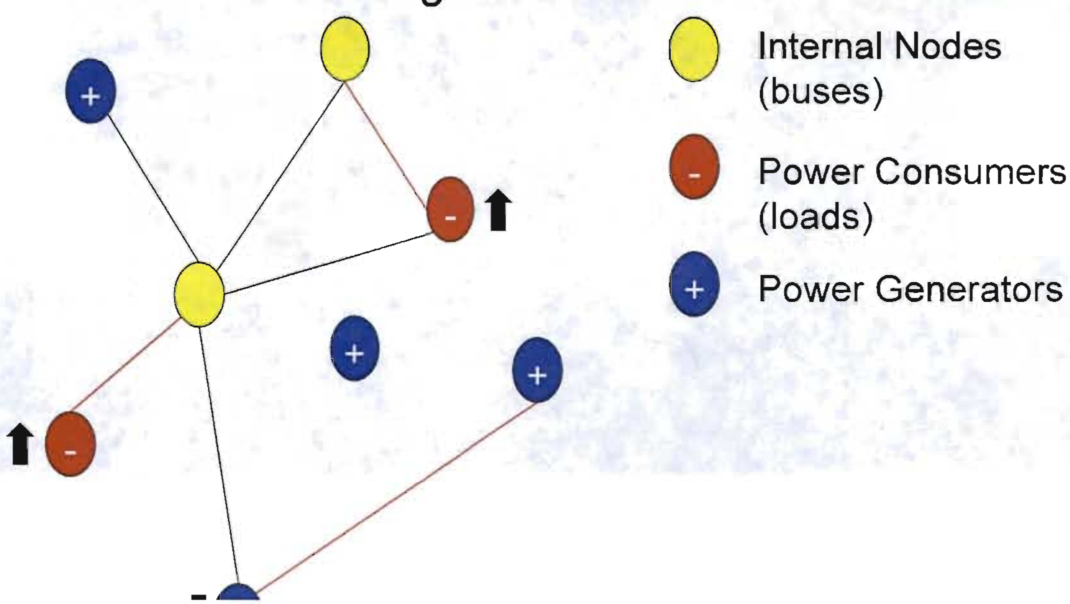

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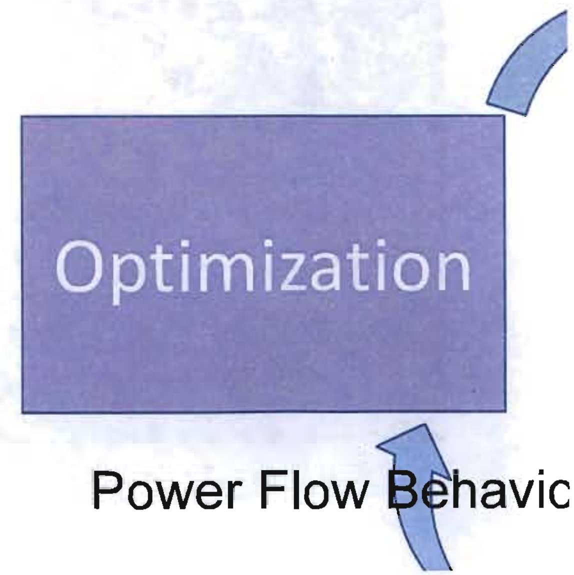

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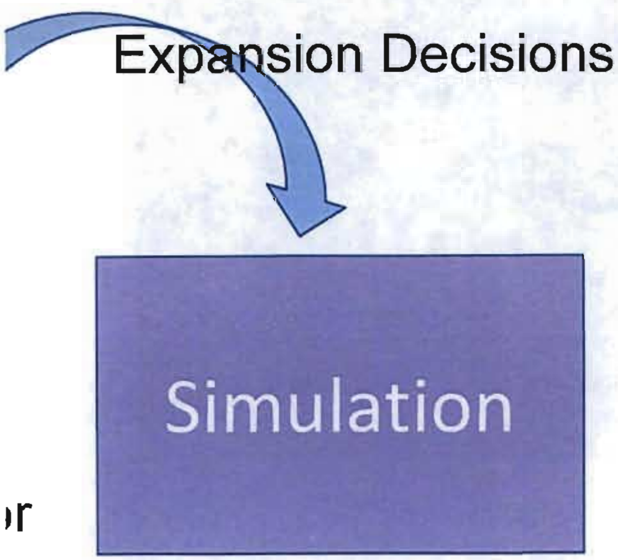

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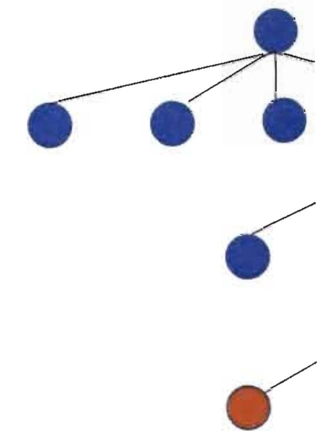

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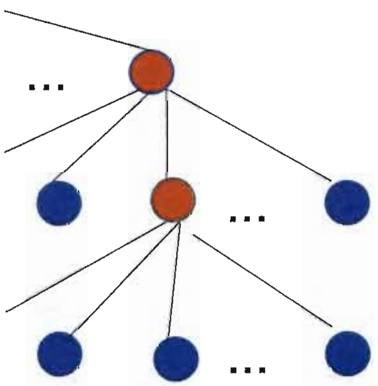

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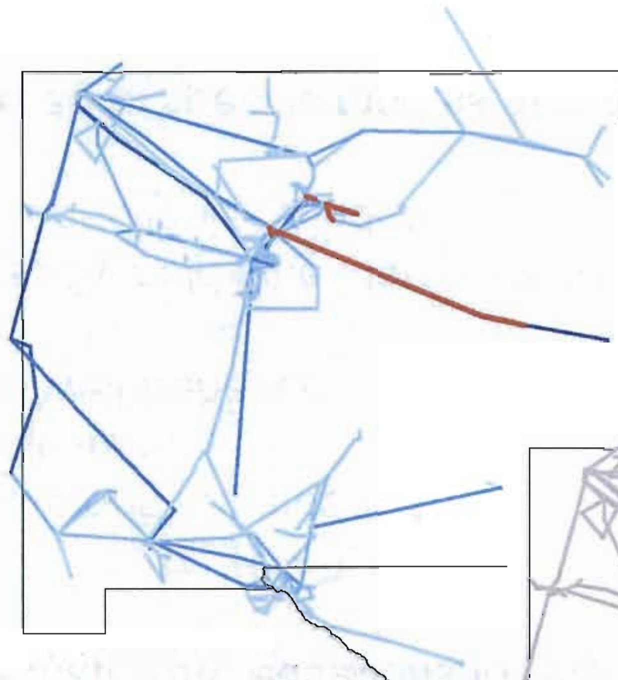

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